HUBBLE SPACE TELESCOPE OBSERVATIONS OF MARS DURING 1996-1997. J.F. Bell III[1], R.T. Clancy[2], P.B. James[3], S.W. Lee[4], L.J. Martin[5], and M.J. Wolff[2], [1]Cornell University, Dept. of Astronomy, Ithaca NY 14853: email jimbo@marswatch.tn.cornell.edu, [2]Space Science Institute, Boulder CO 80303, [3]University of Toledo, Dept. of Physics and Astronomy, Toledo, OH 43606, [4]University of Colorado, LASP, Boulder, CO 80309, [5]Lowell Observatory, Flagstaff AZ 86001.

Summary. We are continuing a long-term program of synoptic monitoring of Mars using the Hubble Space Telescope (HST). The observations are designed to address specific problems in Martian atmospheric composition and dynamics, surface mineralogy, and albedo variations, and to support upcoming Mars Pathfinder and Mars Global Surveyor spacecraft measurements. A total of 21 HST orbits have been dedicated to this program between September 1996 and June 1997, with 19 orbits of WFPC2 imaging and 2 orbits of FOS UV spectroscopy. Initial results from our observational program reveal a substantial increase in Mars atmospheric dust activity compared to the last several apparitions, particularly in the north polar regions.

General Scientific Objectives. Hubble Space Telescope (HST) Planetary Camera images of Mars are ideally suited to the study of dynamic phenomena in the atmosphere and on the surface of the planet. Near oppositions, these images provide "weather satellite" views of the planet with resolution similar to Viking approach pictures and the Daily Global Maps anticipated from Mars Global Surveyor. Even images obtained when the angular size of Mars is only around 5-6 arcseconds (3 to 4 times smaller than at opposition) are sufficient for studying clouds, optical depths, and surface changes. We are continuing our program of Mars observations [1, 2] which commenced in 1990 focussing on the following aspects of the martian environment: (1) The size, location, and optical depth of discrete clouds; (2) The areal extent and optical thickness of hazes; (3) The occurrence of dust storms on the planet; (4) Amounts of dust and ozone in the atmosphere; (5) The seasonal cycle of the martian polar caps and the relationship between the surface caps and the polar hoods; (6) Changes in surface features produced by redistribution of surface dust; (7) Identification and mapping of surface mineralogy.

These objectives are particularly crucial during this apparition because this period immediately precedes the July, 1997 landing of the Mars Pathfinder spacecraft in the Ares Valles region of Mars. We have optimized our program to insure monitoring of the proposed landing site at 19.5°N, 32.8°W in order to determine the history of dust opacity prior to the mission, map mineralology in the landing region, and monitor atmospheric phenomena. Our observations will also support the Mars Global Surveyor mission, which will be in cruise phase during most of this period. Observations and derived quantities (e.g. optical depths) will be shared with the appropriate science teams for the Pathfinder and Global Surveyor Missions. Color composite images will be posted in several formats on publicly-accessible WWW pages as soon as the data are validated.

Observations. HST observations of Mars are limited by the constraint that the telescope cannot point closer than 50° to the Sun. Since the synodic period of Mars is greater than one Martian year, the observable portion of the martian seasonal cycle advances during each HST Cycle; during 1996-97, known as HST Cycle 6, the observable period encompasses early spring in the northern hemisphere (L_s=10°) to mid-summer (L_s=140°). There will be partial overlap with our observations in 1991, 1993, and 1995, allowing intercomparison of four different consecutive Martian years, and Cycle 6 will provide an additional opportunity to separate seasonal from interannual effects. We will observe Mars with 21 orbits of HST between September 1996 and June 1997. 19 orbits will be dedicated to imaging observations with the Wide Field/Planetary Camera 2 (WFPC2) instrument (Table 1). We will utilize 9 filters from the UV through the near-IR, having central wavelengths near 218, 255, 336, 410, 502, 588, 673, 953, and 1042 nm. The remaining 2 orbits will use the Faint Object Spectrograph (FOS) to obtain high spectral resolution UV spectra of Mars for quantitative atmospheric ozone and dust determinations.

Specific Science Goals. The martian season during Cycle 6 corresponds to the occurrence of the largest amounts of water vapor in the martian atmosphere in the northern arctic region. Some models suggest that there is a significant transfer of water from northern to southern hemisphere at this time [3]. Our 1995 HST observations of a planet-encircling band of clouds in the northern tropics from L_s = 60° into the summer season suggests that interhemispheric transport of water may be inhibited by condensation at low levels in the atmosphere. This season is less well documented historically than others because it is observable only near aphelic oppositions. Cycle 6 data will be crucial in establishing the interannual variability of this phenomenon, which may be an important component of the water cycle.

One of the major goals of the Mars HST project has been to observe the development and distribution of dust storms on Mars. This season is separated by half a martian year from that during which the large, planet encircling martian dust storms have historically been observed [4]. Despite this, we observed a large regional dust storm in Utopia at L_s = 82° in 1995 [5]. Similar large regional dust storms were observed by Viking in the arctic region during the year following the major 1977 perihelic storms and may be involved in recycling the dust deposited by the global storms in the north polar region back to the sources in the southern hemisphere. Because of the "snapshot" coverage, the probability of seeing any individual event is clearly small. But the greater density and resolution of this summer solstice season possible during Cycle 6 will enhance this probability.

Discrete clouds are important indicators of meteorological processes on Mars. Martian topographic relief exceeds an atmospheric scale height and will produce fixed eddies in certain locations and seasons which should be revealed by persistent cloud activity. Some of the most interesting and prominent clouds, historically called W clouds, occur in the Tharsis and Valles Marineris regions. We have observed interesting changes in the relative size and optical depth of the components both seasonally and interannually. Coverage of this region at seasonal dates identical to those in 1991, 1993, and 1995 is part of our Cycle 6 plan. The use of four targets equally spaced around the planet will, around opposition, provide the ability to detect cloud motions at speeds > 5 m/sec at the overlap, 45° from the central meridians.

Following a hiatus during Cycles 2 and 3, when contamination prevented the use of the 230 W filter, we have again been able to use a UV pair (255W and 336 W) to study aerosols and ozone in the martian atmosphere [1, 6]. At these short wavelengths, essentially all of the reflected intensity results from atmospheric scattering because of the negligible surface albedo. In the absence of aerosols and ozone, the intensity results from Rayleigh scattering, which can be exactly calculated at both wavelengths. Ozone absorbs strongly in the 255W band but not at 336 nm, and the ratio is therefore a measure of ozone concentration. Departures from Rayleigh scattering can be modeled to provide optical depths of dust and condensate aerosols.

Changes in surface albedo have been observed on Mars for many years. It is now known that these changes result from scouring and deposition of bright dust, especially during the large, planet encircling storms. Based upon frequent, significant changes historically observed in Syrtis Major, we chose that area as our primary repetitive target for Cycles 0-5. Only small changes on the periphery of that region have been seen during the HST observations [1, 2]. However, significant changes have been seen in other areas, especially Cerberus, which has essentially disappeared (to three dark craters) since Viking observations. A shift of our central meridians a few degrees to the east will improve our views of Elysium and Cerberus while still adequately displaying Syrtis. The difference between the behavior we have seen and that based upon Viking experience illustrates the importance of continued global monitoring of the planet.

The reflectance spectrum of Mars reveals broad absorption features which can be used to study the surface mineralology of the planet [7]. Most of the features are due to ferric and ferrous minerals such as hematite, goethite, and high and low Ca pyroxene basalt. The exact positions and depths of the bands depend on the particular minerals which are responsible for the absorptions. Spectral mapping of surface units can identify the particular iron-bearing minerals found on the surface in various regions and therefore help to reveal the weathering and climatic history of the planet. HST images have greater spatial resolution than earth-based observations, but the spectral resolution available with fixed wavelength filters is much less than is possible with spectroscopic techniques. However, judicious selection of narrowband PC filters and of specific linear ramp filter wavelengths allows determination of reflectances at especially diagnostic points in the spectrum [8]. This type of imaging spectroscopy (co-registered multispectral images in 5 to 10 diagnostic wavelengths) will permit greater exploitation of HST's superior spatial resolution in mapping surface units.

Faint Object Spectrograph (FOS) scans of the Mars disk obtained in 1991-1995 show the strong absorption signature of the ozone Hartley bands (240-270 nm) at high latitudes, where the freezing out of atmospheric water vapor leads to enhanced abundances of atmospheric ozone. These FOS scans of Mars have provided the first opportunity to detect low-to-mid latitude abundances of Mars ozone, due to large angular diameter of Mars observed at this time and the improved HST angular resolution. The favorable geometry in Cycle 6 will again occur near Mars aphelion; the cold atmospheric temperatures lead to water vapor saturation above 5-10 km altitudes over the entire Mars globe and are responsible for the equatorial cloud band discovered by HST [2,6]. The 1995 FOS observations reveal substantial increases in Mars atmospheric global ozone associated with this aphelion climate and provide evidence for a predicted annual cycle in the global photochemistry of the Mars atmosphere. Our planned cycle 6 FOS scans for Mars are critical for determining the seasonal extent of this aphelion peak in global Mars ozone, and are particularly favorable for measuring low-to-mid latitude ozone levels during the peak flow of atmospheric water vapor from the northern summer residual ice cap.

Results to Date. The initial results from our Cycle 6 observing program reveal a high level of cloudiness consistent with previous observations of the Martian aphelic atmosphere, as well as an increased level of localized dust storm activity in the north polar region. The latest imaging results will be presented at the conference and can be found online at http://marswatch.tn.cornell.edu/hst96-97.html as well as at http://www.physics.utoledo.edu/~pbj/pathpage.html.

Table 1: 1996-1997 HST GO-6741 Mars Imaging[a]

Date (YYMMDD)	Ls (°)	Size (")	Date (YYMMDD)	Ls (°)	Size (")
960918	11	4.6	~970326b	96	14.1
961008	20	4.9	~970326c	96	14.1
961009	21	5.0	~970326d	96	14.1
961015	24	5.1	~970415	105	13.0
961129	45	6.4	~970519a	120	10.0
961230	58	7.9	~970519b	120	10.0
970104a	60	8.3	~970628a	140	7.6
970104b	60	8.3	~970628b	140	7.6
~970326a	96	14.1	~970628c	140	7.6

[a]Observations after January 1997 not yet obtained.

References: [1] James, P.B. *et al.* (1991) *Icarus, 109,* 79. [2] James, P.B. *et al.* (1996) *JGR, 101,* 18,883. [3] Jakosky, B.M. and R.M Haberle (1992) in *Mars*, U. Ariz. Press, 969. [4] Martin, L.J. and R.W. Zurek (1993) *JGR, 98,* 3221. [5] Wolff, M.J. *et al.* (1997) *JGR, 102,* in press. [6] Clancy, R.T. *et al.* (1996) *Icarus, 122,* 36. [7] Soderblom, L.A. (1992) in *Mars*, U. Ariz. Press, 557. [8] Bell, J.F. III *et al.* (1997) *JGR, 102,* in press.